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ARSENAL OPERATIONS DIVISION
METHODS ENGINEERING BRANCH

TECHNICAL REPORT

SUBJECT: Causes of Polyethylene Rupture Disc Failure

PROBLEM NO.

DATED 4 February 1958

REPORT ON CAUSES

OF

POLYETHYLENE RUPTURE DISC

FAILURE

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Object:

To investigate the cause of polyethylene rupture disc failure in dashpots during field storage.

Introductory Summary and Conclusions:

This investigation was started when examination of dashpots, found to be leaking in the field, revealed that some discs were distorted while others were ruptured. These findings indicated that failures were due to (1) structural weakness of the seal assembly, and (2) a weakness of the polyethylene material. It was decided that Samuel Feltman Ammunition Laboratories would undertake design studies of the components of the seal assembly and that the Atomic Section of the Methods Engineering Branch would explore the conditions that could cause failure due to disc rupture. This report covers the work done by Methods Engineering Branch only.

The following findings have been positively established.

a. The rupture strength of discs depends on the thickness and quality of the section of the polyethylene material from which they are cut.

b. The magnitude of the rupture values depends on both the type (uniform or non-uniform) and speed of load application. The pertinency of these points to the problem will become apparent from the discussion of the results.

1. Thickness of Plastic Polyethylene Sheet

Commercial .002 inch thick polyethylene sheet (sold in 36 inch wide rolls) varies in thickness from 0.0013 to 0.0022 inches across the width of the roll. However, two inch wide strips, cut from the length of the roll, vary only .0002 inch in thickness. This makes it possible to select material of the proper thickness and eliminatesthe need for having to gauge each disc.

2. Quality of Material

a. The quality of polyethylene, as measured by its rupture value, is considerably degraded on exposure to diffused sunlight. The rupture strength will drop at least 20 psi, even on exposure to light of low intensity, over a period of one year.

b. The rate of polyethylene degradation is a function of light intensity and time of exposure. Obviously, unnecessary exposure of the material to light should be avoided.

c. Scratches or indentations on the surface of the disc are not harmful. This was proved by testing material that had been purposely scored with deep cross marks, and finding that the rupture strength at the center of the cross mark was not lowered. Reassuring as these findings are, the criticality of this item makes it advisable to insist on careful workmanship. A good criterion to use would be to require that the circumferential uniformity and surface appearance of the disc comply with that of a standard.

d. The rupture strength of polyethylene was not impaired by contact with Silicone at 175° F. for two hours.

3. Determination of Rupture Strength

The quality of the polyethylene sheet is best judged by its rupture value. In trying to ascertain this value, the following facts came to light.

a. The load must be applied at a uniform rate, otherwise widely varying rupture values can be obtained. Thus, a material, capable of withstanding a pressure of 100 psi under a uniform, slow rate of load application can be ruptured at 2 psi if the load is applied suddenly.

b. The magnitude of rupture values varies inversely with the speed of uniform load application; values of 70 to 100 psi were obtained for the same material from machines operated at different speeds of loading.

c. The equipment for the static test~~, discussed in Section 4,~~ cannot be used for determining the rupture strength because it fails to meet either of the above operational requirements.

d. It is important that discs from a given stock of polyethylene will neither rupture below a specified minimum or fail to rupture below, or at a specified maximum value. To conduct such a test it is (1) mandatory to specify the rate of loading (2) advisable to use equipment by which the pressure can be applied at a uniform and sufficiently low rate so that the rupture values will not deviate more than two percent from the average value, and (3) advantageous to choose equipment which can also be used for carrying out the static test.

e. A Scott Tester, available at Picatinny Arsenal and modified to give a slow rate of load application, was found to be well suited for conducting both tests. The rupture values of the discs deviated only 1.2 percent from the average.

4. The Static Test - Its Significance and Bearing on Inspection

The Static Test requires that a load of 25 lbs be applied and held for five minutes. If the pressure does not drop more than 1 lb., it is assumed that the item was properly assembled and that an unruptured disc had been used.

This test should show up a rupture in the disc which would not be detected by inspection under 10x magnification. (The calculated loss of weight in five minutes through a .0005 inch diameter, .002 inch long hole with an initial pressure of 25 psi and a pressure drop of 1 psi is 2.5×10^{-9} gm.).

The investigation also offered the opportunity to study the present method of filling dashpots and heating the filled item. The results of these tests indicated that it might be advisable to modify both procedures, along the lines indicated in Sections 5 and 6.

5. Filling Dashpots

It is important that (1) the same amount of fluid is used for filling dashpots of a given size, and (2) the volume of the fluid at 160° F. is less than that of the reservoir. Meeting the first condition assures a constant rate of arming, provided the rupture strength of the discs, the viscosity of the fluid, and the dimensions of the hole in the orifice disc all remain constant. Meeting the second condition, assures that rupture failure of the disc cannot occur if the fluid, at any time after assembly, were to reach a temperature of 160° F.

It is confidently predicted that the weight of fluid will deviate less than 0.1 percent from the average if a standard automatic burette of appropriate capacity and calibration is used for measuring the fluid. The amount of fluid required per dashpot is 3.2 ml.

6. Heating Dashpots

The filled dashpot is heated in order to expel most of the air from the reservoir before the closing plug is assembled. This assures the least amount of air entrapment which is desirable because, as pointed out, viscosity affects the rate of arming and viscosity of a fluid is affected by both the amount of air entrapped and its degree of dispersion.

If it is required to obtain a fluid temperature of 160° F. at the time of closing the assembly, the following changes should be made.

a. The present oven should be replaced by one with forced draft circulation.

b. The top oven temperature must be raised to compensate for the drop in the fluid temperature, 10° F., during the closing step.

The writer is happy to express his appreciation to all members of Samuel Feltman Ammunition Laboratories, with whom he had occasion to discuss the various phases of this work, for their open mindedness and whole-hearted cooperation. He also feels indebted to Messrs. G. R. Rugger, W. J. Powers, and Kuch Kuda and other members of Plastic Laboratory, and to O. B. Bronson and his staff of Metal Test Laboratory, for their helpfulness.

RECOMMENDATIONS:

1. Set up a quality standard for polyethylene based on the rupture strength of the disc.

2. Revise the purchase description for polyethylene to include specifications that are applicable to materials that are to be used for rupture discs.

3. Replace the static test equipment (Tinius-Olsen Machine) by one which assures a low rate of uniform loading such as can be obtained with the modified Scott Model DH Tester.

4. Emphasize the importance in the description of manufacture of

a. Using a specified torque when assembling the retaining screw, and

b. Making sure that the screw sets tight, before and after the static test, when a 3 in./lb. torque is reapplied.

5. Fill the dashpots by adding a fixed volume (3.2 ml) of Silicone by means of a suitable automatic burette. Use the hypodermic needle only for removing Silicone if the liquid, just prior to assembling the closing plug, is above the prescribed level.

6. Use an oven with forced draft air circulation to assure uniform temperature conditions throughout the interior.

7. Modify the inspection procedure for the polyethylene tape and discs so that

a. Handling of the materials will be kept to a minimum,

b. Unnecessary exposure to light will be avoided, and

c. Practical supervisory control will be obtainable.

8. The assembly room should be equipped with a hood to prevent the excape of toxic and eye-and-throat irritating vapors into the working area and so constructed as to eliminate dust and corrosive vapor entrainment from adjoining work sections.

INTRODUCTION:

This investigation was initiated when several complaints of leaky dashpots were reported from the field. It was thought that these failures might in part be attributed to having used degraded polyethylene rupture discs. The belief that such discs might have been used was strengthened by these facts: (1) Organic materials, when exposed to unfavorable atmospheric conditions, are susceptible to chemical changes (2) the polyethylene roll, from which the discs had been cut, was over two years old, and (3) the roll had been left exposed to air and sunlight.

Plastic Laboratory suggested that pertinent information on this subject would be found in Technical Report 2102, entitled "Resistance of Plastics to Outdoor Exposure (Robert S. Barrett)." The following information was abstracted from this report:

a. Unmodified polyethylene was found to be generally unsatisfactory for uses which necessitate outdoor exposure over extended periods.

b. The loss in physical properties were generally proportional to the amount of sunlight and the intensity of southerly exposure to which the specimens were exposed.

c. Specimens stored indoors degraded hardly at all.

d. At standard atmospheric conditions, 77° F. and 50 percent relative humidity, polyethylene successfully retained its original physical properties.

e. Based on the results of these tests, "it is clear that heat and sunlight must be the foremost factors in causing breakdown of the polyethylene polymer. Oxidation to the point of chain scission (splitting) which is known to be the mechanism of polyethylene degradation, may then be of two types: (1) thermal oxidation, and (2) oxidation catalyzed by ultra-violet radiation".

f. Polyethylene can be made weather-resistant by incorporating small amounts of an anti-oxidant and an adsorbent of ultra-violet rays.

Based on the findings "c" and "d" in this report, the physical properties of polyethylene stored at the Arsenal should not have changed. However, packing materials are not tested for rupture resistance, therefore, the fact that the elasticity and dielectric strength of polyethylene had remained constant could not be accepted as evidence that its rupture strength had not been affected under these conditions.

I. Degradation Studies of Polyethylene when Exposed to Diffused Sunlight

A. Preliminary Studies

In order to determine whether the rupture strength of the polyethylene roll used for this work had been affected under the prevailing storage conditions, it was decided to determine the rupture strength of polyethylene strips cut from different sections of this roll.

The Mullen Tester was used for determining the rupture strength of the plastic sheet. This equipment is well adapted for this purpose because the load is applied at a uniform rate, the machine is easy to operate and the results are quickly obtained.

The test piece holder consisted of two 0.25" thick, lap finished steel discs with a 0.125" diameter coined center hole the size of the hole in the retaining screw.

Three 4" by 30" strips were cut, one from each side and one from the middle of the roll. The rupture strength was determined at ten points along the medians spaced approximately 2.5" apart. The results are shown in Table I.

TABLE I

Rupture Strength in PSI of Polyethylene Strips Cut from Indicated Position of Roll Exposed to Diffused Sunlight

Test No.	Left End	Middle	Right End
1	65.5	62.0	70.0
2	74.0	65.0	70.0
3	64.0	64.0	68.0
4	64.0	56.0	70.0
5	66.0	59.0	72.0
6	67.0	58.5	69.0
7	63.5	55.0	68.0
8	68.0	57.5	69.0
9	70.0	55.5	69.0
10	71.0	55.5	72.0
Average	67.3	58.8	69.7
Maximum Deviation	10	10	4

Maximum Deviation - Difference between maximum and minimum rupture values of 30 tests - 19 psi

CONCLUSIONS:

1. The results of the preliminary tests indicated that the Mullen Tester and the test assembly were well suited for determining the rupture strength of polyethylene sheet.

2. The large variation, 19 psi, between the maximum and minimum rupture values of the 30 tests, indicates that similar variations could have been encountered in practice.

3. The fact that the middle strip had an average rupture strength ten psi less than that of the end strips indicated that the thickness of the polyethylene sheet is not uniform.

4. What could not be explained was the fact that the lowest rupture value in the 30 tests was greater than the highest that was obtained when the same material was tested in the Tinius-Olsen Machine.

B. Final Tests

Discussion:

The roll of polyethylene from which the discs were cut had been stored on top of a 4.5' high bin in the tool room of the punch press section in the Inert Components Branch. The bin was about 18' from a window with westerly exposure. The top of the bin was about 2.5' below the window. In this position, the quadrant facing the window was exposed to slanting rays of diffused sunlight of the greatest intensity, the opposite quadrant to those of least and the two other quadrants to rays of intermediate intensity. Hence, if diffused sunlight has a deteriorating effect on the rupture strength of polyethylene, it should follow that one quadrant strip should have the highest rupture strength, the one opposite it the lowest and the other two intermediate values.

In order to see whether (1) the thickness of the sheet varied, and (2) polyethylene had degraded on exposure to diffused sunlight, the following experiment was run.

Test Procedure

Four 6" wide by 36" long strips were cut from the width of the subject roll, each strip representing a different quadrant of one turn of the roll. These strips were marked to identify the order in which they were cut.

Nine 4" wide sections were laid off along their length. The thickness was measured to 0.0001" along both 36" sides at a point midway between the ends of each test section. The rupture strength was then determined near the center of each of these 36 sections.

The results are shown in Table II and the corresponding graphs on Chart I.

TABLE II

Thickness and Rupture Strength of Four Quadrant Strips Representing One Turn of Polyethylene Roll Used for Rupture Discs

Strip No.	I			II			III			IV		
Section No.	Thickness in 10-4" Measured Along		RS in PSI	Thickness in 10-4" Measured Along		RS in PSI	Thickness in 10-4" Measured Along		RS in PSI	Thickness in 10-4" Measured Along		RS in PSI
	B	T*		B	T*		B	T*		B	T*	
1	18.0	20.0	60.0	20.0	19.0	70.5	18.0	20.0	68.5	19.0	19.5	56.0
2	22.0	20.0	69.0	15.0	21.0	74.0	21.5	20.5	74.0	20.0	21.0	64.0
3	20.0	19.5	63.5	25.0	20.0	72.0	20.0	20.0	71.5	18.0	20.0	56.0
4	20.0	20.0	63.0	21.0	20.0	72.5	22.0	21.0	72.5	20.0	20.5	62.0
5	20.5	21.0	64.0	22.0	22.0	78.0	20.0	21.5	74.0	22.0	22.0	62.0
6	17.0	18.0	62.0	16.0	16.0	60.0	17.0	17.0	59.5	18.0	17.0	52.0
7	20.0	19.0	64.0	19.0	19.0	71.0	20.0	19.0	68.0	20.0	19.0	59.0
8	15.0	15.0	46.5	15.0	15.0	53.0	15.0	15.0	52.0	15.0	15.0	46.0
9	21.0	21.0	62.0	20.0	21.0	70.0	20.0	20.0	70.0	20.0	21.0	61.0

The insert in the upper right hand corner of Chart I illustrates the probable exposure conditions during storage.

The assigned quadrant positions correspond to their respective rupture ratings. Thus, the strip with the lowest rating IV should have been facing the light which would place the opposite quadrant II in the shade. Quadrants I and II would have to be located as shown to correspond to their respective rupture ratings.

CONCLUSIONS:

1. From the graphs it is seen that the rupture strength throughout the whole length of each quadrant strip cut from one turn of the polyethylene roll differs consistently from the corresponding rupture values of the other strips. Thus, Strip II had the highest values, IV the lowest and Nos. I and III intermediate ones.

2. The fact that the numerical order of the four strips agrees with the rupture strength to be anticipated from the prevailing storage conditions, proves that the rupture strength of polyethylene is degraded on exposure to diffused sunlight over an extended period.

3. The thickness of the sheet varied considerably along its width, i.e., from section to section, but very little along its length, i.e., per section. The extent of these variations can be better visualized from the graph on Chart II showing the thickness measurements, a total of eight per section, for each of the nine positions of the four strips.

*B - Bottom
T - Top

4. The thickness of the polyethylene sheet along its width is much greater over the right than the left portion of the roll.

5. The thickness values for the same position, i.e., along the length of the roll, are fairly consistent. However, one value each in the second and third sections deviates by 0.0005", or 25 percent, from the respective averages, whereas the maximum deviation in the remaining seven sections is 0.0002", or only ten percent.

6. It is more than likely that occasional past failures of rupture discs could have been caused from inadvertently having selected discs that had been cut from a thinner section of the polyethylene roll.

II. Relation Between the Thickness and Rupture Strength of Polyethylene Sheet

Discussion

The rupture strength of a material, other conditions remaining constant, is a function of its thickness. Hence, graphs based on the thickness and rupture values, shown in Table II, should form a family of straight lines when plotted on coordinate paper.

But which thickness should be used in plotting these graphs? Should it be the average of the two measurements per section? The average of the eight measurements along each sectional length? Or that particular value falling in the maximum-minimum range of the eight measurements which would best fit the graph?

The writer contends that the last choice is the one to be made because (1) the rupture test was made near the center of each section whereas the sheet's thickness was measured near the borders, and (2) as was pointed out, several thicknesses of the four sectional strips along their length deviated markedly from the respective average values. Hence, this procedure was used in plotting the graphs shown on Chart III.

The data in Table III are self explanatory.

TABLE III

STRIP II

Position	R.S. psi	Thickness as 10^{-4} in. Avg	*	Deviation 10^{-5} in.	%
8	53.0	15.0	15.0	0.0	0.0
6	60.0	16.0	16.5	5.0	3.1
9	70.0	20.0	19.5	5.0	2.5
1	70.5	19.5	19.6	1.0	0.5
7	71.0	19.0	19.7	7.0	3.7
3	72.0	22.5	20.0	25.0	11.0
4	72.5	20.5	20.0	5.0	2.5
2	74.0	18.0	20.5	25.0	14.0
5	78.0	22.0	21.5	5.0	2.3
	Average			9.0	4.7

STRIP III

Position	R.S. psi	Thickness as 10^{-4} in. Avg	*	Deviation 10^{-5} in.	%
8	52.0	15.0	15.0	0.0	0.0
6	60.0	17.0	17.2	2.0	1.2
9	70.0	20.0	20.0	0.0	0.0
1	68.5	19.0	19.5	5.0	2.6
7	68.0	19.5	19.4	1.0	0.5
3	71.5	20.0	20.0	0.0	0.0
4	72.5	21.5	20.5	10.0	4.5
2	74.0	21.0	20.9	1.0	0.5
5	74.0	20.75	20.9	1.5	0.7
				2.3	1.1

STRIP I

8	46.5	15.0	15.0	0.0	0.0
6	62.0	17.5	18.0	8.0	2.8
9	62.0	21.0	20.0	10.0	5.0
1	60.0	19.0	18.7	3.0	1.6
7	63.0	19.5	19.5	0.0	0.0
3	63.5	19.75	19.6	1.5	0.8
4	63.0	20.0	20.0	0.0	0.0
2	69.0	21.0	21.0	0.0	0.0
5	64.0	20.75	20.0	7.5	3.8
	Average			3.0	1.5

STRIP IV

8	46.5	15.0	15.0	0.0	0.0
6	52.0	17.5	17.5	0.0	0.0
9	61.0	20.5	20.0	5.0	2.5
1	56.0	19.75	18.8	9.5	5.5
7	59.0	19.5	19.5	0.0	0.0
3	56.0	19.0	18.8	2.0	1.0
4	62.0	20.25	20.3	0.5	0.3
2	64.0	20.5	20.8	3.0	1.5
5	62.0	22.0	20.3	17.0	8.0
				4.0	1.8

*Selected

$$\% \text{ Deviation} = \frac{\text{Numerical Deviation}}{\text{Average Thickness}} \times 100$$

Conclusions

From an inspection of the family of graphs on Chart III, the following conclusions can be drawn:

a. The rupture strength of the polyethylene sheet is proportional to its thickness, the quality of the polyethylene remaining constant.

b. The thickness varies inversely with the quality of the polyethylene, the rupture strength remaining constant.

c. The graphs enable one to calculate the percent relative degree of degradation. For this purpose one reads either the film thicknesses corresponding to constant rupture value, or the rupture values for any constant sheet thickness. The data and calculated quality ratings are shown in Table IV.

TABLE IV

Quadrant from which Material was Cut	Thickness Expressed in 10^{-4} inches at Constant Rupture (60 psi)	Rupture Value in psi for Same Thickness (0.002")	% Relative Quality of Material
II	16.8	72.5	100
III	17.2	70.0	87
I	18.7	65.0	37
IV	19.8	61.0	0

III. Study of the Effect of Non-Uniform Rate of Load Application on the Rupture Strength of Polyethylene Discs

INTRODUCTION:

Once again, the lowest rupture value among the 36 tests was greater than the highest obtained when discs from the polyethylene sheet of highest rupture strength were tested in the Tinius-Olsen Machine. This anomalous behavior led to the decision to study the standard testing procedure.

The test machine is an old Tinius-Olsen model. The load is applied by manually turning an unbalanced 12 inch diameter wheel which is connected to a vertically moving shaft by an eccentric cam.

The test assembly, comprising a holding fixture and a dashpot, is placed on the bottom platen, the loading side, of a beam scale. The load is varied by sliding a weight to any desired position on the calibrated beam.

After the test assembly is placed in the machine, the set-up is adjusted for zero load. The weight is then moved to the 25 pound mark and the wheel is turned until the bottom of the vertical plunger comes to rest on the detent of the dashpot. The pointers of two dial indicators are then placed against the fixture so that on release of the pressure, the dial readings will drop below the initial settings. This occurs if the disc is ruptured. When this happens fluid will start to escape from the reservoir and will unbalance the equilibrium condition between the applied load and the pressure on the detent. Since the load remains constant, the beam will sink, the loading end of the scale will rise, the pressure on pointers of the indicators will be released and therefore, the dial readings will drop.

If the dial readings remain constant for five minutes, the pressure on the detent is released, the load on the beam is increased by five pounds, and the aforementioned procedure is repeated until the disc is ruptured. The rupture strength of the disc is expressed thus, passes "a lbs", fails at "a + 5 lbs).

It is well known that tension, compression and shear values of a material are influenced by the rate and uniformity of load application; these conditions apply even more to the rupture strength of materials of relatively low elasticity, or high plasticity. Such materials become permanently disfigured at relatively low pressures causing the thickness to attenuate. Therefore, an uneven rate, or too high a speed of load application could conceivably result in reducing the thickness of the disc far more than would be the case were the load applied more uniformly and/or more slowly.

In order to see whether the Tinius-Olsen rupture value of the polyethylene discs would be increased under more uniform loading conditions, the following test procedure was tried.

Instead of using the handle, the wheel was moved in the following manner:

a. Two fingers of one hand were placed near the top and on opposite sides of the wheel.

b. Two fingers of the other hand were similarly placed on the wheel close to the first pair of fingers.

c. The wheel was turned by inching the rear set of fingers back and forth while the front set was used to brake the speed. The pertinent data from these tests are shown in Table IV.

TABLE IV

Method of Loading	Loading Conditions: Initial Load (in pounds)	Loading Conditions: Load Increment (in pounds)	Rupture Strength in lbs.: Passed	Rupture Strength in lbs.: Failed at
Standard	25	5		25
	25	5	25	30
	25	5	30	35
Modified	5	5	55	60
	10	10 lbs. up to 30 lbs., 5 lbs. thereafter	50	55
	30	5	35	40

CONCLUSIONS:

1. The results of these tests conclusively show that the low rupture values obtained from the Tinius-Olsen Machine by the standard method can be appreciably increased by simply altering the method of load application.

2. The effect of non-uniform loading becomes apparent from the fact that the rupture values drop when the initial load is increased. Thus, doubling the initial load (from five to ten pounds) reduces the rupture strength eight percent, increasing the load sixfold (from five to thirty pounds) resulted in a drop of 33 percent.

3. The effect of varying the rate of uniform load application could not be determined because, for obvious reasons, a manually applied load, even under the most favorable conditions, can not be expected to proceed at a uniform rate.

IV. To Determine the Effect of Varying the Rate of Uniform Loading on the Rupture Value of Polyethylene Discs

Discussion

If a dashpot assembly withstands the stipulated static load (25 lbs), it means that (1) it is tight, and (2) the disc is not ruptured. However, the fact that the assembly passes this test gives no assurance that the disc would either not rupture below a specified minimum load or rupture below a specified maximum load. Should such specifications have to be met at a later date, it would be well to know that suitable test equipment is available.

The Mullen Tester could be used only for determining the rupture strength of the polyethylene sheet; it is not adapted for conducting the static test. The Tinius-Olsen Machine can be used for both purposes, but the rupture value results obtained are far from reliable. Obviously, it would then be desirable to have one machine which would be suitable for conducting both tests.

Most, if not all, standard tensile testing equipment can be easily adapted for determining the rupture strength of the disc in the assembly and for testing the tightness of the assembly. The following machines being available at the Arsenal, were therefor used for determining the rupture value of the polyethylene disc in assembled dashpots:

A Baldwin-Southwark Universal Testing Machine
Dillon Tensile Tester
Hand-operated Hydraulic Ram
Two Models of Scott Tester

Tests with Baldwin-Southwark Universal Testing Machine

Discussion:

One disc was cut from each of the nine sections of the strips of the highest and lowest ratings, respectively Nos. II and IV, obtained from the Mullen Tester. The discs were cut out close to the place where the Mullen tests had been made. The load was applied at the lowest controllable speed.

The results are shown in Table V and the pertinent graphs on Chart IV.

The same equipment was used for determining the effect on rupture strength of continued contact of the plastic with Silicone. These results will be found in Section VI of this report.

TABLE V

	Strip No. II				IV			
	Rupture Strength in lbs. from		Thickness in 10^{-4} in. used for graphs		Rupture Strength in lbs. from		Thickness in 10^{-4} in. used for graphs	
Sect. No.	Mullen	S-B	Mullen	S-B	Mullen	S-B	Mullen	S-B
8	53.0	40.0	15.0	15.0	46.5	300	15.0	
6	60.0	50.0	16.5	17.5	52.0	25.0	17.5	17.0
9	70.0	55.0	19.5	20.0	61.0	300	20.0	
1	70.5	50.0	19.6	18.0	56.0	45.0	18.8	19.8
7	71.0	25.0*	19.7	19.0	59.0	300	19.5	
3	72.0	60.0	20.0	20.4	56.0	56.0	18.8	22.3
4	72.5	60.0	20.0	20.4	62.0	300	20.3	
2	74.0	70.0	20.5	22.0	64.0	50.0	20.8	21.0
5	78.0	60.0	21.5	20.4	62.0	55.0	20.3	22.0

Discussion of Results:

1. The low rupture value of disc from Section 7 (*) was due to improper assembling. Examination showed that this disc was distorted but not ruptured whereas the others clearly showed the typical annular impression of the O-Ring on the periphery and the uniformly raised dome on the inner surface of the disc.

2. The abnormally high loads were obtained on the old type of dashpots (Nos. 4, 7, 8 and 9) which require a shorter guide pin. The longer pin protruded into the hole for the filling pin thus causing the load to be transferred to the pin instead of the fluid.

Conclusions:

1. The graph of the Baldwin-Southwark rupture values vs. the disc thickness again is a straight line proving that consistent results can be obtained from this machine.

2. The Baldwin-Southwark rupture values are approximately 13 lbs. lower than the Mullen.

3. The rupture value of degraded polyethylene discs less than 0.0018" thick, falls within the range of values obtained from the Tinius-Olsen machine.

Tests with Other Testing Equipment

Discussion:

The polyethylene used in these tests was cut from freshly manufactured 0.002" thick plastic stock. This material was received 25 September 1957 from the Gering Corporation of Kenilworth, New Jersey, the supplier of the rolls of polyethylene in the Arsenal.

The discs were cut from a 3" wide by 12" long strip cut from the length of the sheet. Its thickness along both 12" sides and in the center, varied not more than 0.0001". The pertinent data are given in Tables VI, VII and VIII.

TABLE VI

Machine	Dillon Tensile Tester			Hydraulic Ram			Southwark-Baldwin Heated Dashpots			Universal Tester Unheated Dashpots		
No. Test	RV psi	Deviation a	b	RV psi	Deviation a	b	RV psi	Deviation a	b	RV psi	Deviation a	b
1	30	2	7	40	34	46.0	50	18	26.5	50	11	18.0
2	34	6	21	60	14	19.0	60	8	11.8	55	6	9.8
3	20	8	28	63	11	14.9	60	8	11.9	60	1	1.6
4				65	9	12.2	65	3	4.4	60	1	1.6
5				69	6	8.1	65	3	4.4	60	1	1.6
6				70	4	5.4	70	2	2.9	60	1	1.6
7				72	2	2.7	70	2	2.9	60	1	1.6
8				72	2	2.7	70	2	2.9	65	4	6.6
9				72	2	2.7	70	2	2.9	65	4	6.6
10				75	1	1.4	80	12	17.7	65	4	6.6
11				80	6	8.1	85	17	25.0	70	9	14.7
12				83	9	12.2						
13				83	9	12.2						
14				85	11	14.9						
15				88	14	10.0						
16				90	16	21.6						
17				92	18	24.3						
Average	28		19	74		13.4	68		10.3	61		6.4

a - Numerical
b - Percentage

TABLE VII

Scott Tester Model DH

Torque for Closing Retainer Screw in inch-lbs.	2.5			5.0			10.0		
No. Test	RV psi	Deviation a	b	RV psi	Deviation a	b	RV psi	Deviation a	b
1	75	19.3	20.4	94	4.1	4.2	98	1.8	1.8
2	89	5.3	5.6	94	4.1	4.2	98	1.8	1.8
3	93	1.3	1.4	95	3.1	3.2	98	1.8	1.8
4	94	0.3	0.3	98	0.1	0.1	99	0.8	0.8
5	95	0.7	0.7	99	0.9	0.9	99	0.8	0.8
6	95	0.7	0.7	100	1.9	1.9	99	0.8	0.8
7	95	0.7	0.7	101	2.9	2.9	100	0.2	0.2
8	96	1.7	1.8	101	2.9	2.9	101	1.2	1.2
9	98	3.7	3.9	101	2.9	2.9	101	1.2	1.2
10	98	3.7	3.9	101	2.9	2.9	101	1.2	1.2
11	102	7.7					101	1.2	1.2
12	102	7.7	8.2				101	1.2	1.2
13							101	1.2	1.2
14							101	1.2	1.2
15							101	1.2	1.2
Average	94.3		4.7	98.1		2.0	99.8		1.2

TABLE VII

Resume of Rupture Data Obtained from Different Testing Equipment

Type of Testing Machine	Description of Assembly	No. of Tests	R.V.	Average Percent Deviation
Dillon Tensile Tester	Standard	3	28	19.0
Hydraulic Ram	Standard	17	74	13.4
Southwark-Baldwin	Heated Dashpots	11	68	10.3
Southwark-Baldwin	Unheated Dashpots	11	61	6.4
Scott Tester	Torque 2.5 inch-lb.	12	94.3	4.7
Scott Tester	Torque 5.0 inch-lb.	10	98.1	2.0
Scott Tester	Torque 10.0 inch-lb.	15	99.8	1.2

Conclusions:

1. The hand-operated Dillon Tensile Tester is even less satisfactory than the Tinius-Olsen Machine because its rate of load application is faster and more difficult to control.

2. A hand-operated hydraulic ram is also unacceptable for the same reason. However, if the load could be mechanically applied at a uniform, slow rate consistent results should be obtained. Such equipment would then have the advantages of low cost, small operating space requirement and simplicity of operation.

3. The Southwark-Baldwin Machine gives fairly consistent results. Its high cost and large size are disadvantages and, because the speed of loading is still too great, the results deviate more than is desirable.

4. The Scott Tester is well suited for both tests. It can be easily modified to operate at a sufficiently low speed to give extremely consistent rupture values.

V. Quality of Polyethylene Sheet from Roll vs. that Cut from Fresh Material

The graphs on Chart V show the rupture values obtained from the Mullen Test of different polyethylene sheets. The data in Table IX are taken from these graphs.

TABLE IX

Rupture Values, in lbs, of Polyethylene at Indicated Position of Strip

Position	Old Roll Quadrant II: Cut from Width	Fresh Material: Cut from Width	Fresh Material: Cut from Length
1	70	67	76
2	74	73	74
3	71	69	72
4	72	74	75
5	74	75	79
Average	72.2	71.6	75.2
6	60	82	73
7	68	88	78
8	52	80	79
9	70	77	77
10		74	75
Average	62.5	80.2	76.4

TABLE X

Deviations of Average Rupture Values

Description of Material	Average Rupture Value: Pos'n 1-5	Pos'n 6-up	Pos'n All	Deviation of Average RV: Average Value for Positions 1-5	6-up	Avg of Both Dev.
Quadrant II, from old roll (Highest RV) cut from width	72.2	62.5	67.8	4.4	5.3	4.75
New Material from width	71.6	80.2	75.9	4.3	4.3	4.3
New Material from length	75.2	76.4	75.8	0.6	0.6	0.6

Conclusions:

1. The average of the deviations of the two sections of each plastic specimen shows that the thickness of the material cut from the length is about eight times more uniform than that cut from the width.

2. The overall average of the rupture values of the two strips cut from the fresh material, 75.8 and 75.0, indicate that the quality of the material is uniform.

3. The material represented by Quadrant II of the old roll, the one of the highest rupture rating, had also degraded during storage, its average rupture value being eight lbs. less than that of the fresh material. That this condition should have been obtained was to be expected because all sides of the roll must have been exposed to diffused sunlight at one time or another over the storage period of one year.

VI. Expansion of the Fluid

The dashpot serves as a safety and arming mechanism so long as the disc remains unruptured and/or the fluid in the reservoir has not been expelled. If the polyethylene used for the discs meets the specified quality requirements and the assembly has been properly assembled, premature rupturing of the disc could still occur if the volume of the enclosed fluid at 160°F. is greater than that of the reservoir and the fluid were to reach this temperature prior to functioning.

Now, the rate of fluid discharge, which determines the rate of inward movement of the detent and therefore the rate of arming, is a function of (1) the dimensions of the opening in the orifice disc, and (2) the flow characteristics of the fluid. Assuming that the proper orifice disc and grade of Silicone were used, the rate of liquid flow will depend solely on its kinematic viscosity, $v = \frac{u}{p}$ where u is the viscosity and p the density. Both viscosity and density will vary with temperature but the viscosity can also be affected by the amount of entrained air and the degree of its dispersion in the fluid.

The present method of filling, heating and closing the dashpot was considered as not giving enough assurance that a disc might not be ruptured if a dashpot assembly were to reach a temperature of 160°F. in the field. This deduction was based on the following premises:

1. It is questionable whether the specified holding time is long enough and oven temperature is high enough to raise the temperature of the enclosed fluid to 160°F.

2. It was surmised that the temperature of the fluid in all dashpots would not be the same because an oven, depending on gravity convection currents for circulating the air, does not produce a uniform temperature throughout all parts.

3. Because the room is 80° to 90° F. below the oven temperature and the closing step is performed outside, the fluid temperature would be less than 160° F. after the closing step has been completed.

4. The visual adjustment of the level of the warm fluid should be made when the prescribed level is horizontal with the line of sight. Since this condition can not be met, the result is open to error.

The tests described in this section were conducted to ascertain whether the foregoing deductions were valid and, if so, what changes should be made to obtain the desired end results.

VII. Test Procedure for Determining the Temperature - Time Upheat Curves of the Oven Air and the Enclosed Dashpot Fluid

a. Nine filled dashpots were placed on the middle rack, three in each of the back, center and front rows.

b. The hot junction of a constantan-nickel thermocouple was passed through the vent in the top of the oven and immersed in the fluid of Dashpot No. 5, the one in the middle of the center row.

c. The glass thermometer for measuring the oven temperature was inserted in the vent opening next to the thermocouple leads.

The up-heat time vs. temperature curves for the oven air and the enclosed fluid in Dashpot No. 5 are shown on Chart VI.

Conclusion:

The oven temperature reaches equilibrium after 66 minutes, that of the fluid after 110. Hence, if the assemblies are placed in a "cold" oven of the type now being used, they must remain in it 50 minutes after the specified maximum oven temperature has been reached.

VIII. Procedure to Determine the Fluid Temperature and Air Temperature of and Around Dashpots Located in Different Parts of the Oven

Procedure:

The hot thermocouple junction was placed successively in each assembly (a transfer requiring from five to seven seconds). The potentiometer was read after the oven temperature had returned to 161° F. The same procedure was used for measuring also the ambient air temperatures in the vicinity of each assembly. The results of these tests are shown in Tables XI, XII and XIII and the corresponding graphs on Chart VI.

TABLE XI

Dashpot Fluid Temperatures at Oven Temperature of 161° F.

Position of Dashpot Listed in Order in which Temperatures were Obtained	Initial Reading	Temperature Data Final Reading	Temperature Change
1	154	156	2
2	151	154	3
3	150	150	0
6	146	148	2
4	146	149	2
7	143	148	5
8	148	148	0
9	140	145	5
5	145	148	3

TABLE XII

Air Temperatures near Assemblies

5	144	148	4
4	148	150	2
6	144	148	4
1	148	159	11
2	153	157	4
3	150	150	0
9	142	148	6
8	147	150	3
7	143	148	5

TABLE XIII

Difference Between Air and Fluid Temperatures

Position of Dashpot	Temperature Data Temperature After Oven Temperatures had Returned to 161° F.			Difference Between Temperatures After Thermocouple Transfer to New Location and Oven Temperatures had Returned to 161° F.		
	Air	Fluid	Difference	Fluid	Air	Average
1	159	156	3	2	11	6.5
2	157	154	3	3	4	3.5
3	150	150	0	0	0	0.0
4	150	148	2	2	2	2.0
5	148	148	0	3	4	3.0
6	148	148	0	2	4	3.0
7	148	148	0	5	5	5.0
8	150	148	-2	0	3	1.5
9	148	145	3	5	6	5.5

TABLE XIII

Resume of Temperature Data

Dashpot in Position	No. of Items	Difference Between Temperatures of Fluid	Air	Average of Difference
3	1	0	0	0
1	1	2	11	6.5
Back Row	3	1.7	5.0	3.4
Middle Row	3	2.3	3.3	2.8
Rear Row	3	3.3	3.7	3.5

Conclusions:

1. The air in location (3) is most qiescent, in location (1) most turbulent and across the middle row most uniform.

2. If an oven with natural convection is used, the dashpots should be placed only in the center row of the middle rack because in other locations, the desired fluid temperature would not be reached in the specified time.

IX. Experiment to Determine the Top Oven Temperature at which the Fluid Temperature, after Sealing the Assembly, will be Not Less than 160° F.

Procedure:

The thermocouple was immersed in Dashpot 9, where the lowest fluid temperature was obtained and the oven temperature was raised until the fluid temperature reached 160° F.

The closing operation of the dashpot was then timed. It took about ten seconds.

The drop in temperature, over a span of ten seconds, was then determined at 150° and 160° F. From these data the cooling curves, shown on Chart VII, were obtained.

Conclusions:

1. The rate of energy loss during cooling follows Newton's Law of Cooling. ($A = C(T_a - T_b)$ where C, a constant, is proportional to the area and depends on the surface conditions, and T_a and T_b are the initial and final temperatures, respectively). Since the area and surface conditions of the dashpots can be considered to remain constant, the rate of energy loss - should be proportional to the temperature difference and the graphs should be straight lines. From the cooling curves, it is seen that the temperature drops at 160° F. and 150° F. are 9.5° F. and 9° F., respectively.

2. If the more exact Stefan-Boltzman Law is used for calculating the heat loss, the values for 150° to 180° F., check within one percent.

3. If a final fluid temperature of 160° F. is to be obtained, the oven temperature should be raised to at least 176° F.

X. Filling Dashpot with Silicone Fluid

The rate of fluid discharge through a ruptured disc under the applicable conditions depends on:

a. The dimensions of the openings in the orifice disc,

b. The amount of fluid in the dashpot, and

c. The kinematic viscosity of the fluid.

Since the kinematic viscosity can be affected by the amount of entrained air and its degree of dispersion, it is obvious that the most uniform rate of fluid discharge, i.e., rate of arming, will be obtained when both the weight of fluid and the volume of entrained air remain constant. These objectives cannot be attained by the present method of filling because the fluid is not measured quantitatively and, as already mentioned, the method of adjusting the liquid volume is not accurate. It was believed that a quantitative method of measuring the fluid would overcome both objections. To test the feasibility of this idea, the following experiment was run.

The average amount of fluid in the dashpots was determined, as follows:

Several assemblies were filled in the usual manner. After completing all operations, the fluid was expelled from the dashpot and measured by sucking it up into the hypodermic needle. The average volume was found to be 3.2 ml.

Twelve dashpots were assembled. Six were filled in the usual manner and six by adding 3.2 ml. from the hypodermic needle. The latter assemblies were not heated. The dashpots were weighed before and after filling. The data are shown in Table XIV.

TABLE XIV

Method - Standard Method

Weight of Dashpot in gms. Empty	Filled	Weight of Fluid by Difference	Deviation from Average Gms.	Percent
206.83	209.95	3.12	0.07	2.18
206.73	209.60	2.87	0.32	10.00
204.33	207.50	3.17	0.02	0.63
206.43	209.85	3.42	0.23	7.22
206.53	209.90	3.37	0.18	5.53
206.93	210.10	3.17	0.02	0.63
Average		3.19		4.36

Methods - By Adding 3.2 ml. from Hypodermic Needle

Weight of Dashpot in gms. Empty	Filled	Weight of Fluid by Difference	Deviation from Average Gms.	Percent
206.43	209.80	3.37	0.00	0.00
206.83	210.20	3.37	0.00	0.00
207.03	210.30	3.27	0.10	2.97
206.63	210.05	3.42	0.15	4.45
206.83	210.15	3.32	0.05	1.49
206.24	209.70	3.46	0.09	2.67
Average		3.37		1.93

Conclusions:

1. Filling dashpots by adding a predetermined volume of fluid more than doubles the reliability of the results.

2. The maximum deviation in the results by the approved and suggested methods if 0.55 gms., and 0.19 gms., respectively.

3. The results would check very much better by using a 10 ml. automatic burette calibrated in 0.05 ml. This type of equipment is also preferred because the chances of contaminating the fluid are greatly reduced since (a) the burette reservoir (five pint capacity) could serve as the receiver of the filtered fluid, and (b) moisture and dust in the air can be effectively removed by adsorbent.

XI. Effect of Warm Silicone Fluid on the Rupture Strength of Polyethylene

Introduction:

The possibility that prolonged contact of polyethylene with Silicone might affect its rupture strength had also been considered. To determine what effect would be produced, the following test was conducted.

Twenty-four dashpots were assembled with the old type of O-ring and spacer. The rupture discs were cut from the fresh polyethylene material. Twelve dashpots were heated at 175° F. for one hour, the others were not heated. The pertinent data are shown in Table XV, the graphs on Chart VIII.

TABLE XV

Rupture Strength of Fresh Polyethylene Material Received 25 September 1957 by Mullen Test

Position No.	Width of Roll Thickness		Width of Roll RS	Width of New Sheet Thickness		Width of New Sheet RS	Length of New Material Thickness		Length of New Material RS
1	20	19	70.5	20	19	67	20	20	76
2	15	21	74.0	20	20	73	20	20	74
3	25	20	72.0	20	20	69	20	21	72
4	21	20	72.5	18	20	74	21	19	75
5	22	22	78.0	20	21	75	21	20	79
6	16	16	60.0	22	21	82	21	20	73
7	19	19	71.0	23	23	88	21	20	78
8	15	15	53.0	24	21	80	21	20	79
9	20	20	70.0	20	21	77	21	20	77
10				20	21	74	21	21	75
Average	19.17		69.0	20.8		75.9	20.4		75.8
Max. Dev.	0.0007		25	0.0006		21	0.0002		7

The results of the rupture values of the disc in the heated and unheated assemblies are shown in Table VI of Section IV.

Conclusions:

1. The deviations in the thickness and rupture strength along the width of the new polyethylene material are about the same as those of the corresponding strip cut from the old roll. However, the average rupture values of the new material is 7 psi greater, indicating, as previously mentioned, that all parts of the roll had been degraded on exposure to diffused sunlight.

2. The thickness of the sheet cut from the length is about three times more uniform than the thickness of a sheet cut from the width.

3. Contrary to expectation, the rupture strength of polyethylene is not deleteriously affected by contact with Silicone. As a matter of fact, the average rupture value of the heated discs is raised 6 lbs.

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--    TECHNICAL REPORTS STATISTICS  PAGE  1 OF  2  JUN 04, 1992

--TOTAL-SEARCH FINDS**----------------        1      ARMY--       0
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--   FIRST AND SECOND LEVEL FINDS**---        0      AF----       0
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--                         ***DTIC DOES NOT HAVE THIS ITEM***
-- 1 -  AD NUMBER: D406548
-- 3 -  ENTRY CLASSIFICATION:    UNCLASSIFIED
-- 5 -  CORPORATE AUTHOR: PICATINNY ARSENAL  DOVER NJ
-- 6 -  UNCLASSIFIED TITLE:      CAUSES OF POLYETHYLENE RUPTURE DISC FAILURE.
-- 8 -  TITLE CLASSIFICATION:    UNCLASSIFIED
--10 -  PERSONAL AUTHORS: MAHLER,P.;
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--20 -  REPORT CLASSIFICATION:   UNCLASSIFIED
--27 -  ABSTRACT:    THIS INVESTIGATION WAS STARTED WHEN EXAMINATION OF
--      DASHPOTS, FOUND TO BE LEAKING IN THE FIELD, REVEALED THAT SOME
--      DISCS WERE DISTORTED WHILE OTHERS WERE RUPTURED. THESE FINDINGS
--      INDICATED THAT FAILURES WERE DUE TO (1) STRUCTURAL WEAKNESS OF THE
--      SEAL ASSEMBLY, AND (2) A WEAKNESS OF THE POLYETHYLENE MATERIAL.
--      (AUTHOR, MODIFIED).
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--30 -  ANNOTATION: CAUSES OF POLYETHYLENE RUPTURE DISC FAILURE.
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--35 -  SOURCE CODE:        282900
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--41 -  TYPE CODE:   A

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--42 -  IAC ACCESSION NUMBER:       PL-002028
--43 -  IAC DOCUMENT TYPE:
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--44 -  IAC SUBJECT TERMS:        P--(U)DISCS, RUPTURE STRENGTH,
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